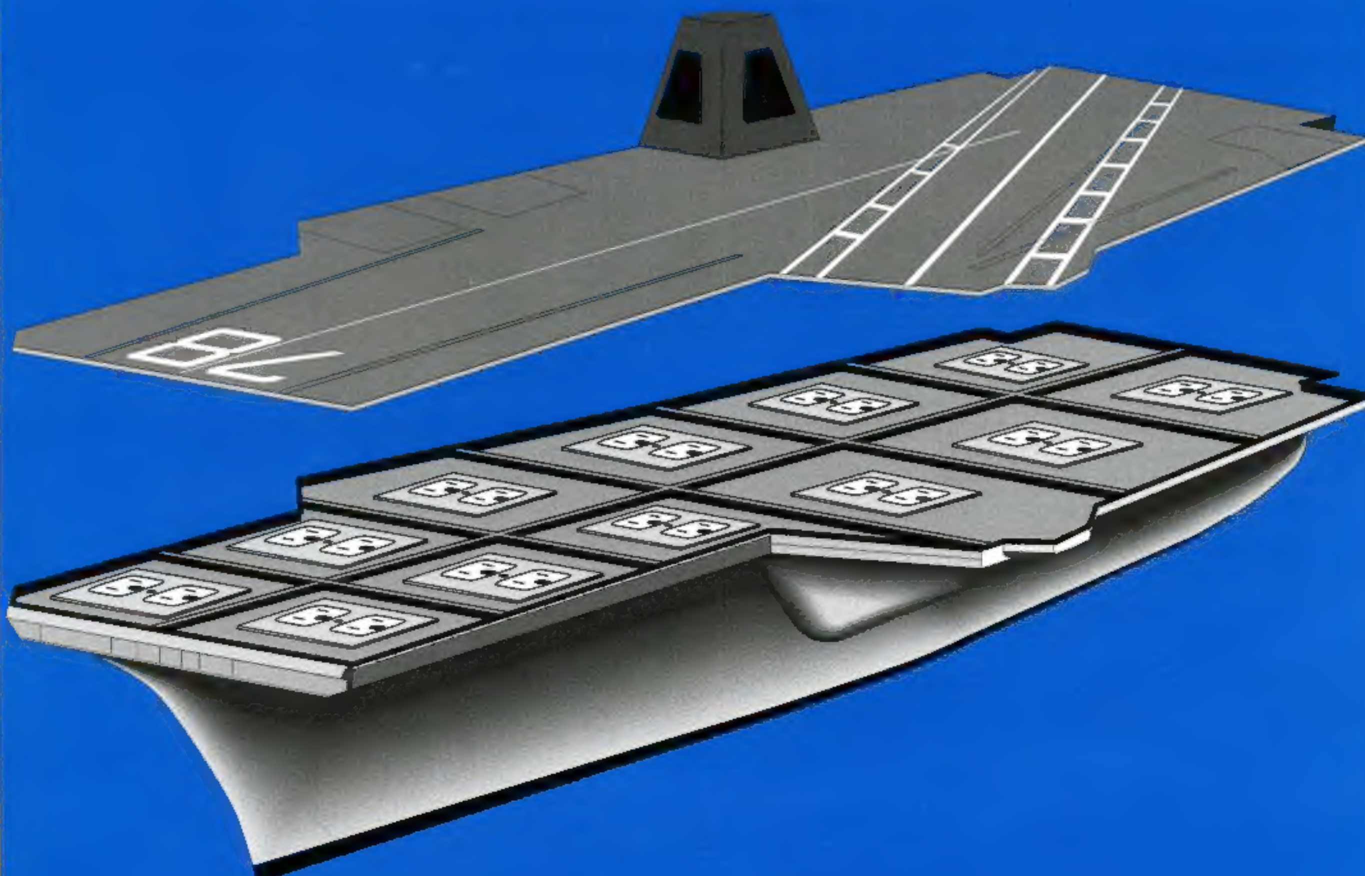
Naval Research Advisory Committee Report

# CVX Flexibility

October 1997



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**13. ABSTRACT (Maximum 200 words)**

NRAC identified science and technology opportunities to benefit engineering and operational flexibility of CVX, the future aircraft carrier, and other new ship classes. The panel consisted of industry and government experts and former Navy admirals with extensive carrier operations experience. They consulted with experts on carrier technologies and conducted interviews with senior Naval aviators.

The panel recommended that future aircraft carriers be large, nuclear powered, all-electric ships with modular architecture. These characteristics provide maximum operational flexibility, rapid and affordable reconfigurability for enhanced damage control, ready adaptation to new missions and adoption of new technologies.

Large carriers provide flexibility to support large airwings, future manned/unmanned aircraft, joint and international missions, humanitarian operations, and flight operations in heavy sea states. Nuclear propulsion offers proven advantages in speed, range and self-sustainability. An all-electric design provides flexibility to support future weapons systems. Survivability against future threats must be a design priority; the panel recommended requiring reduced acoustic and electromagnetic signatures to decrease targeting opportunities. Early implementation of a design-build approach; adoption of proven commercial methods and technologies for reducing manning, operations, maintenance and constructions costs; and technology development to eliminate expensive mid-life overhauls will promote affordability.

**14. SUBJECT TERMS:** CVX, aircraft carrier, nuclear power, electric power, modular architecture, operational flexibility, manned/unmanned aircraft, flight operations, weapons systems, survivability, affordability, design-build methodology, acoustic/ electromagnetic signature, reduced manning, forward presence, training, damage control, maintenance

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Committee Report

# CVX Flexibility

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OFFICE OF THE ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, DEVELOPMENT AND ACQUISITION)

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# Executive Summary

In January 1997 the Naval Research Advisory Committee (NRAC) was tasked by the Honorable John Douglass, Assistant Secretary of the Navy (Research, Development and Acquisition [ASN (RD&A)], to conduct a study of science and technology (S&T) opportunities that might beneficially impact the engineering and operational flexibility of CVX as well as other new classes of Navy ships. Sponsors of the NRAC study on CVX flexibility were RADM Michael T. Coyle, Deputy Commander for Engineering, Naval Sea Systems Command (NAVSEA) and RADM Dennis V. McGinn, Director, Air Warfare Division (N88), Office of Chief of Naval Operations (OPNAV). In order to credibly address the broad range of issues associated with CVX flexibility, a panel of seven NRAC members was augmented with experts from industry and government as well as two former Navy flag officers with extensive carrier operations experience.

To maximize flexibility, CVX must be effective, available, reconfigurable, and affordable. **Effectiveness** is the ability to undertake any assigned mission, ranging from strike warfare to humanitarian, and to perform under all weather conditions. For CVX to be **available,** anywhere and anytime, requires a high speed sprint capability. Once on station, CVX must have the endurance to perform its mission for as long as necessary. A critical key to CVX availability is its ability to survive in the 21st century threat environment. In order to (1) minimize operational limitations due to damage, (2) adapt quickly and effectively to new missions, and (3) adopt new technologies as required during the life of the ship, CVX must be rapidly and affordably **reconfigurable**. If today's problems of a Department of the Navy (DON) budget dominated by personnel, operating and maintenance costs are to be mitigated in the future, the <u>requirement</u> for life cycle **affordability** must be incorporated from the first conceptual stages in the design, construction, manning, operation and maintenance of CVX.

The Panel concluded that CVX must be designed to support a large (80 aircraft) airwing and conduct flight operations in heavy sea states in order to execute the most demanding power projection missions. The challenge is to ensure that CVX can normally be operated effectively with a smaller airwing, but can be surged to a larger airwing appropriate for the most stressing missions on short notice. If successfully executed, this strategy will reduce operating costs during peacetime while retaining critical flexibility to meet the most demanding power projection requirements. Sustained high speed sprint capability is necessary if CVX is to be available for rapidly evolving crises. A nuclear-fueled power plant will provide the ability for CVX to operate in this mode without impinging upon aviation fuel and ordnance capacities necessary for sustained operation. Survivability requires attention to reduction of signatures, adoption of adequate protection measures, and the ability to recover from damage.

An essential element of CVX flexibility is the ability to rapidly and affordably reconfigure for damage control, adapt for new missions and adopt new technology. A key to lifetime CVX affordability is an all-electric ship with modular architecture. The all-electric ship, with its common source of power for all systems, can be rapidly reconfigured in case of damage--power can be redirected to undamaged propulsion systems or mission critical combat systems. A modular architecture with large accessible spaces and standardized utility interfaces will allow CVX to be rapidly reconfigured for different missions. Over the 50-year service life of CVX, several generations of aircraft, Command, Control, Communications, Computers and Intelligence ($C^4I$) and Hull, Mechanical, and Electrical (HM&E) technologies must be accommodated. The combination of a modular architecture, which allows rapid reconfiguration of mission critical payload and support spaces, and the all-electric ship, with its universal power source, is the only approach that can accommodate these anticipated changes in a cost effective manner.

Four major features of CVX flexibility are delineated: (1) for maximum availability, the ship should have a **nuclear** propulsion plant; (2) for maximum effectiveness, in all weather and for all missions, the ship must be **large**, on the order of 100,000 tons, and (3 and 4) finally, to be optimally reconfigurable, **modular architecture** and a common source of **electric** power are essential.

For a large, nuclear-powered carrier to be affordable for the future, major reductions are required in ship manning, operation and maintenance (O&M) costs, as well as construction costs. Proven commercial methods and technologies for automating watch-standing functions, handling of supplies and reducing maintenance requirements offer low risk approaches to affordability in many areas. In order to best control O&M costs, the Panel recommends that CVX be designed with the goal of eliminating the mid-life overhaul. The rapid reconfiguration capability provided by an all-electric ship and modular architecture should reduce O&M costs by reducing the length and frequency of shipyard availabilities.

It is considered imperative that the CVX design/build team be selected and funded early, that it include participants who represent the users and maintainers as well as the designers and builders and that the team be empowered to identify and resolve life cycle cost related issues. In order to minimize design cost and to ensure that attention is focused on those issues requiring Research and Development (R&D) investment, it is necessary to fix the design drivers (i.e., ship size, type of power plant, etc.) as soon as possible in the integrated design process. The commercial shipbuilding industry, in order to be competitive in the world market, has adopted many manufacturing and construction methods that reduce the cost of building ships. Many of these practices may be applicable to naval construction; however, current design standards for Navy ships may preclude their use. It is

essential that these modern commercial methods be given full and careful consideration in the design process.

By insisting on an all-electric ship, the DON will ensure O&M savings, reconfiguration flexibility and arguably, design and construction savings as well. This is equally true for both conventionally and nuclear powered ships. The ability to rapidly and affordably reconfigure for damage control, changing missions and changing technologies must be designed into CVX from the beginning. The all-electric ship concept supports this approach. Large areas, high in the ship, must be provided with easy access and standard interfaces to allow rapid exchange of pre-equipped, mission specific modules. Elsewhere in the ship the $C^4I$ systems, combat systems and HM&E equipment installations should be modularized or palletized to allow for rapid exchange.

In summary, the NRAC CVX Flexibility Panel found arguments favoring large, nuclear powered carriers to be persuasive when considered in the light of reduced overseas bases and the wide spectrum of rapidly evolving crises which are likely in the 21st century environment. In order to take best advantage of this potential, CVX should be an all-electric ship with modular architecture to allow for rapid and affordable reconfigurability for enhanced damage control, adaptation to new missions and adoption of new technologies. Survivability against probable 21st century threats must be a priority for CVX designers and this requires the reduction of acoustic and electromagnetic signatures to decrease the likelihood of being targeted. Affordability should be pursued through adoption of proven commercial methods and technologies for reducing manning, O&M and construction costs.

## CVX Flexibility Terms of Reference

**General Objective:** Identify science and technology opportunities that have the potential for major impact on engineering and operational flexibility over the lifetime of new Navy ship classes now under consideration.

**ASN(RD&A) Sponsors**

| | |
|---|---|
| **RADM Dennis V. McGinn** | Dir. Air Warfare Division (N88), Office of Chief of Naval Operations |
| **RADM Michael T. Coyle** | Dep. Commander for Engineering, Naval Sea Systems Command |

In January 1997, the NRAC was tasked by the Honorable John Douglass, ASN(RD&A) to conduct a study of S&T opportunities that might beneficially impact the engineering and operational flexibility of CVX, the 21st century replacement for the Nimitz class aircraft carriers of today, as well as other new classes of Navy ships. The Terms of Reference for the study are given below:

**TERMS OF REFERENCE**
**NAVAL RESEARCH ADVISORY COMMITTEE**
**CVX FLEXIBILITY PANEL**

**General Objective:** Identify S&T opportunities that have the potential for major impact on engineering and operational flexibility over the lifetime of new Navy ship classes now under consideration.

**Background:** The lead ship of the CVX class is currently scheduled for completion in 2013. The CVX class of aircraft carriers is intended to have a useful service life of approximately 50 years. During this lifetime, the class is likely to experience 2 to 3 generations of prime power and propulsion technologies, 3 to 4 generations of naval aircraft, and 8 to 12 generations of $C^4I$ technologies. Throughout the course of such changes, it is essential that CVX class ships maintain their preeminent role as projectors of naval air power for the widest spectrum of missions.

**Specific Tasking:**

- Consider CVX requirements, concept of operations, roles, and missions to analyze capabilities and ship configurations related to engineering flexibility.

- Identify potential technical limitations to CVX operational flexibility over the lifetime of the class.

- Recommend specific S&T initiatives, such as integrated electric power and electric drive, to address such limitations.

- Consider the applicability of such initiatives to other current and new Navy ship classes.

Sponsors of the NRAC study on CVX flexibility were Rear Admiral Michael T. Coyle, Deputy Commander for Engineering, NAVSEA and Rear Admiral Dennis V. McGinn, Director, Air Warfare Division (N88), OPNAV.

NRAC

## CVX Flexibility Panel Membership

| | | |
|---|---|---|
| **Chairperson** | | |
| Prof William F Weldon* | Josey Centennial Professor in Energy Resources | University of Texas at Austin |
| **Vice Chairperson** | | |
| Dr Patrick H Winston* | Professor of Computer Science | MIT Artificial Intelligence Lab |
| Mr John M Bachkosky | Corporate VP , Advanced Technology | System Planning Corporation |
| Mr Ronald L Bannister | Manager Emerging Technology Programs | Westinghouse Electric Corp |
| Mr Thomas A Brancati* | Avionics/C⁴I Consultant | Retired CEO, Whittaker Inc |
| VADM R M Dunleavy USN (Ret ) | Private Consultant | |
| Mr Peter A Gale | Chief Naval Architect | John J McMullen Associates |
| VADM E R Kohn USN (Ret ) | Private Consultant | |
| Dr James R Luyten* | Senior Associate Director | Woods Hole Oceanographic Inst |
| Mr Alan Newhouse | Private Consultant (Propulsion Systems) | |
| Dr Irene C Peden* | Professor Emerita (Electrical Engineering) | University of Washington |
| Dr Eugene A Silva | Head ONR S&T Education Project | Office of Naval Research |
| Dr Anna Maria Skalka* | Scientific Director & Senior Vice President | Fox Chase Cancer Center |
| **Executive Secretary** | | |
| CDR Michael E McMahon, USN | Deputy Design Director CVX Prog | Naval Sea Systems Command |

*Naval Research Advisory Committee Members

In order to credibly address the broad ranging issues associated with CVX flexibility, a panel of seven NRAC members was augmented with experts from industry and government as well as two retired Navy flag officers with extensive carrier operational experience. Specific areas of panel expertise include electromechanics, artificial intelligence and automation, Department of Defense (DoD) acquisition policies, advanced gas turbines, avionics, $C^4I$, carrier architecture, marine meteorology, naval propulsion systems, antenna technology and microbiology.

The NRAC CVX Flexibility Panel was chaired by Professor William F. Weldon. Dr. Patrick H. Winston served as the Vice Chair and Commander Michael E. McMahon, USN (Ph.D.), Deputy Design Director, CVX Program, served as the Executive Secretary.

## Briefings/Visits

- 29 briefings
- 7 interviews
- 5 field trips
- Review of previous aircraft carrier studies
- Review of additional technical, historical, policy and programmatic material

To address the task of studying the future aircraft carrier in a constrained time frame, a rigorous schedule of briefings was conducted in three 3-day sessions between 14 May and 25 June 1997 to examine current S&T efforts being considered for CVX and related programs, the current and prospective role of the aircraft carrier in national defense policy, the expected concept of operations for CVX, programmatic information, and information on the expected and potential aircraft for use on CVX.

In addition to the briefings, numerous interviews were conducted with individuals who have significant aircraft carrier expertise and/or operational experience. A past and present view of naval aviation was presented during two of these interviews by Vice Admiral Don Engen, USN (Ret.) and Vice Admiral Brent Bennitt, USN, who is currently the Commander Naval Air Force Pacific. Vice Admiral Engen, a World War II ace and distinguished civil servant (former Director of the Federal Aviation Adminsistration (FAA) and current Director of the Smithsonian Institution National Air and Space Museum), provided a perspective on 50 years of naval aviation. Vice Admiral Bennitt is the head of the Naval Air Board and is closely involved with all aspects of naval aviation.

Time was also allotted for review of the numerous aircraft carrier studies conducted over the past 20 years and to interview the authors of those studies as they were available. Mr. Tom Taylor of the Center for Naval Analyses and Mr. Peter Gale, a member of the CVX Flexibility Panel, were extremely helpful in identifying and summarizing relevant aircraft carrier studies of the recent past. Efforts were made to obtain information from outside the DON including other government agencies, private institutes, industry, and Royal Navy (UK) programs relevant to CVX development.

A list of briefings, interviews and field trips is presented in Table I.

Table I
BRIEFINGS / INTERVIEWS / VISITS

| Briefing Topic | Briefer | Title/Organization |
|---|---|---|
| CVX Program | CAPT T. Manvel, USN | CVX Program Manager, NAVSEA |
| Requirements | CAPT T. Webb, USN | OPNAV (N885) |
| Nuclear Propulsion | ADM Frank Bowman, USN | Director, Naval Nuclear Propulsion (NAVSEA 08) |
| Nuclear Propulsion | Mr. D. Pye<br>Mr. W. Schmitt<br>Mr. J. Gist | NAVSEA 08 |
| COEA/AOA | Dr. Dave Perrin | Center for Naval Analyses |
| Concept of Operations | Mr. K.T. Moore | Whitney, Bradley, Brown, Inc. |
| CV Design Review | Mr. Jim Raber | NAVSEA 03D |
| Advanced Aviation Concepts | Mr. Rus Perkins<br>CAPT Frank McCarty, USN | NAVAIR 4.OT |
| CVX R&D | Mr. John Christian | NAVSEA PMS 378 |
| UK Integrated Propulsion System | COMO Frank Mungo, RN | British Royal Navy |
| Integrated Power System FSAD Program | Mr. Mike Collins<br>LCDR John Amy, USN<br>Mr. David Fennel | Lockheed-Martin |
| CV Conventional Propulsion | Mr. Jim Dunne | NAVSEA 03Z |
| Ship Signatures | Mr. Kurt Yankaskas | NAVSEA 03T |
| Joint Strike Fighter Program | CAPT Walt Rogers, USN | JSF Program |
| Ship Environmental Issues | Mr. Tom Allen<br>Mr. Rich Guida | NAVSEA 03L<br>NAVSEA 08 |

| | | |
|---|---|---|
| Plasma Arc Incinerator | Mr. Bruce Sartwell | NRL |
| Future Antenna Technology | CAPT Hap Perry, USN<br>Mr. Paul Hughes | ONR<br>NRL |
| Common Support Aircraft | CAPT Gary Peterson, USN | OPNAV (N88) |
| R&D Investment for Reduced Life Cycle Costs | Mr. John Schank | Rand Corporation |
| CV Presence | Dr. Jackie Davis | Institute for Foreign Policy Analysis |
| $C^4I$ Technology for CVX | Dr. James Norton<br>Mr. Robert McFadzean<br>Mr. Steve Vipavetz | NSWC - CD<br>NSWC - CD<br>NAVSEA PMS 378 |
| Podded Propulsor Technology | Dr. Peter Majumdar | ONR IFO (Europe) |
| Active Armor | Dr. Darrell Garrison | NSWC - CD |
| Alternative Catapult/Arresting Technology | Mr. Dick Bushway | NAVAIR |
| Active Noise Quieting | Dr. Jeoffrey Main | ONR |
| DD-21 Hull Concepts | Ms. Karin McIntyre | ONR |
| Remote Sensor Technology | Ms. Pat Woody<br>Mr. John Bozewicz<br>Mr. Anthony Seman<br>Mr. Joel Perry | NSWC - SSES<br><br><br>Draper Labs |
| CV Survibability | Mr. John Schell | NAVSEA 03P |
| Future CV Technology | Mr. Larry Dubois | DARPA |

<u>Interviews:</u>
VADM B. Bennitt, USN - Commander, Naval Air Force Pacific Fleet
VADM D. Engen, USN (Ret.)
VADM A. Less, USN (Ret.)
RADM D. Sargent, USN, NAVSEA, PEO-CLA
RADM J. Wilson, USN (Ret.)
RADM R. Mixon, USN (Ret.)
Mr. T. Taylor - Center for Naval Analyses (Retired)

Field Trips:
USS YORKTOWN (CG 48) "Smart Ship"
Newport News Shipbuilding Innovation Center
USS EISENHOWER (CVN 69)
NRaD Electromagnetic and Advanced Technology Division
USNS BOWDITCH

## Our Crystal Ball

- **Changing political environment**
  - Declining budgets
  - Reduced overseas bases
  - Decreasing US military force
- **No single predictable threat**
  - Asymmetric threats
  - Geographically dispersed
  - Technologically sophisticated
- **Origin of crisis**
  - Population growth
  - Shortage of oil, food, water
  - Religious, ethnic, political tensions
  - Economic imbalance

Of the 172 overseas airbases built by the US since World War II, we have access to 24 today. Some of these were lost through reduction in service manning levels and budgets, while others were the result of changing national policies. All indications are that this trend will continue; our overseas bases are not likely to increase. Unfortunately, crises and threats to our security will.

Although the Soviet Union no longer exists as a military superpower, a large number of militarily capable nations who are real and potential adversaries do exist throughout most of the world. Crises and conflict can erupt anywhere on the globe. Today and into the future, virtually all countries and many other groups have access to advanced, high technology weapons. Unsophisticated and inexpensive, but deadly, chemical and biological devices can be produced by rogue states or terrorists. Massive, detectable movement of troops and equipment may no longer be relied upon to forecast the initiation of conflict. Future crises will emerge and spread quickly unless discouraged or contained by the presence of an effective force.

The aircraft carrier provides that effective force. It offers an alternative to lost overseas bases in the form of a rapidly mobile, flexible aerodrome, capable of appearing anywhere along the world's coastlines, at any time, to maintain the peace by discouraging aggression or, when that fails, to restore peace through the application of surgical or massive military force.

## CVX will be the forward presence:

- Rapid response to contingencies
- Credible deterrent
- Joint platform
  - Special Ops
  - USA/USAF
  - JFACC
- Multi-national missions
- Humanitarian missions

Because of their mobility, wide-ranging offensive power and ability to conduct sustained operations off the coasts of potential aggressors, forward-deployed aircraft carriers constitute a critical portion of our national crisis-response capability. The availability of aircraft carriers has often spelled the difference between successful resolution of an international crisis and a foreign policy failure.

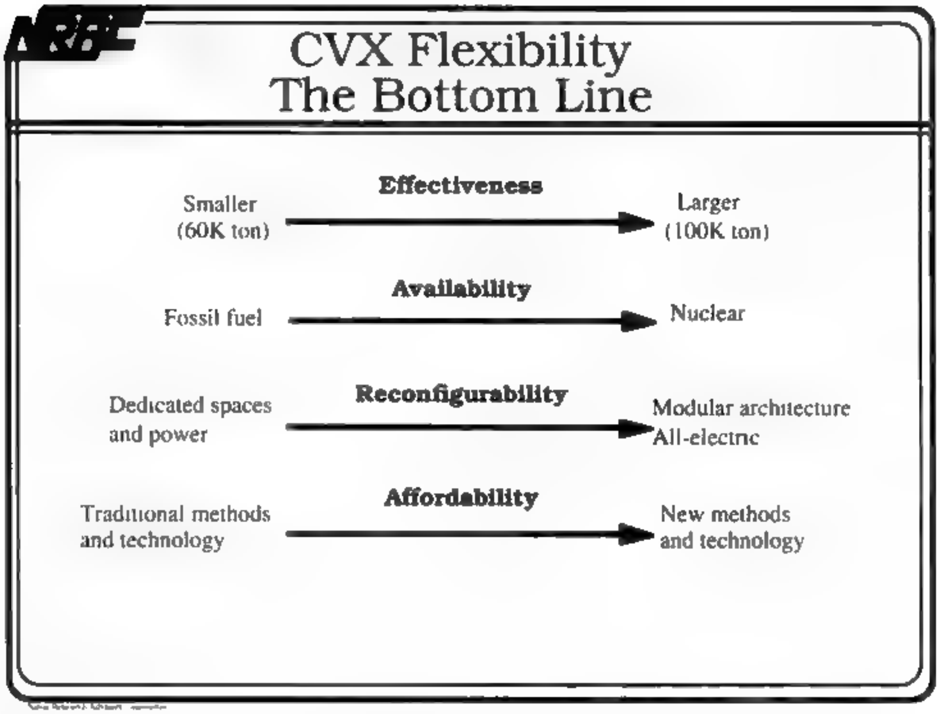
The flexibility inherent in our aircraft carriers enables the National Command Authority to tailor US response to impending threats or crises. This may involve a CV operating alone, as part of a Carrier Battle Group, as a platform for Special Operations, or as a Joint Force Air Coordination Center. The ability to operate cooperatively with military forces of other nations will become even more diplomatically important in the next century. Inherent in the size, rapid mobility and operational flexibility of the carrier is its value in responding to natural disasters and humanitarian missions. Although not its primary mission, this additional capability has proven to be a valuable asset and will continue to be needed in the future.

## CVX Flexibility Requirements

- Effective
  - All missions
  - All weather
- Reconfigurable
  - Damage control
  - New missions
  - New technologies
- Available
  - Anywhere, anytime
  - Survivable
  - As long as needed
- Affordable
  - Design/build
  - Manning
  - O & M

To maximize its flexibility, CVX must be effective, available, reconfigurable, and affordable. **Effectiveness** is the ability to undertake any assigned mission, ranging from strike warfare to humanitarian, and to perform under all weather conditions. In order for CVX to be **available,** anywhere and anytime, a high speed sprint capability is required. Once on station, CVX must have the endurance to perform its mission for as long as necessary. In particular, CVX must be self-sustaining for the first few days on station until slower replenishment ships begin arriving in the area. A critical key to CVX availability is its survibability in the 21st century threat environment.

In order to (1) minimize operational limitations due to damage; (2) adapt quickly and effectively to new missions; and (3) adopt new technologies as required during the life of the ship, CVX must be rapidly and affordably **reconfigurable**. If today's DON budget problems which are dominated by personnel, operating and maintenance costs are to be mitigated in the future, the requirement for life cycle **affordability** must be incorporated from the first conceptual stages in the design, construction, manning, operation and maintenance of CVX.




A preview of the CVX Flexibility Panel's principal conclusions is presented at this point in order to place the balance of the presentation in the proper context.

CVX must be large to be effective. The large size is critical to successful execution of the most demanding missions since it provides the ability to conduct flight operations in high sea states. Additionally, larger ships offer the necessary internal capacity to sustain demanding missions as well as to rapidly accommodate new missions.

A sustained high speed sprint capability is necessary if CVX is to be available for rapidly evolving crises. A nuclear-fueled power plant will provide the ability for CVX to operate in this mode without impinging upon the aviation fuel and ordnance capacities necessary for sustained operation.

Dedicated equipment spaces and mixed mechanical, electrical, hydraulic, steam and pneumatic power sources on today's Navy ships make significant reconfiguration of the ship slow and expensive. CVX and other Navy ships for the 21st century must be flexible and easily reconfigurable in order to effectively perform the wide spectrum of anticipated missions with an affordable number of platforms. CVX should be designed with large, externally accessible spaces and standardized utility interfaces to allow rapid extraction and insertion of mission specific modules. HM&E equipment and combat systems should also be palletized, with standardized utility hook-ups, so that they can be quickly and economically exchanged when appropriate. If ship's power is universally available in electrical form and specialized utility requirements are provided on individual modules, reconfigurability will be enhanced.

The Navy has a long and successful history of designing and operating ships. This vast body of experience brings with it much tradition as well as many lessons learned. In some aspects, such as shock hardening and damage control requirements, Navy ships are currently and must continue to be unique from commercial ships. In many other areas, including modular construction, corrosion control, electric drive, automation and reduced manning, the commercial sector has made great strides in recent years, driven by the same economic forces now faced by the Navy. In order to assure that the DON is able to afford the military capabilities required to accomplish its missions, new, more affordable methods and technologies must replace the Navy's more traditional approaches wherever they are appropriate.

## CVX Flexibility - **Effectiveness**

- All missions
  - Ability to rapidly reconfigure
  - Maximum use of aviation assets
  - Full situational awareness
  - Secure and reliable communications
- All Weather
  - Ship size

The critical areas in which CVX must to be effective are in (1) its ability to successfully execute all assigned missions, and (2) its ability to conduct operations to be independent of weather conditions. To execute all assigned missions, CVX must be able to change rapidly from Navy-only configurations to accommodate joint operational requirements, and perform non-military and humanitarian missions, as well as unforeseen future missions. The ship must be able to accommodate technology upgrades with minimal disruption to operations. The CVX design must accommodate and support present and future aircraft, including CTOL, VSTOL, VTOL, UAVs and UCAVs. In addition, individual missions may require different numbers and mixes of aircraft.

The effectiveness of CVX will depend upon timely and appropriate situational awareness for all operators and maintainers, which is based upon fusion of onboard and off-board sensor data, to facilitate intelligent decision making. Such awareness must include knowledge of the internal condition of the ship and status of shipboard systems, as well as full awareness of complex and rapidly evolving external situations.

As an effective stand-alone platform, battle group flagship, or joint or cooperative engagement platform, the security and reliability of high data-rate internal and external communications are essential. Forward deployed naval forces are increasingly dependent upon the availability, quality and integrity of massive amounts of information to carry out their mission. The coordination of fleet operations has become dependent upon connectivity ashore and afloat for real-time situational awareness. The demand for this information has resulted in increasing fleet reliance upon satellite networks to provide this connectivity. The rate of information transfer continues to grow and to tax the capability

of military Satellite Communications (SATCOM) systems. As a result, the use of purchased or leased commercial SATCOM services is now required. The DON must ensure that its operational procedures incorporate the necessary awareness and training to prevent exploitation of secure information over these commercial links.

It is critical that shipboard information and communications systems deliver timely messages and visuals to appropriate recipients. A central requirement for ensuring that this capability exists on CVX is providing a high bandwidth fiber optic backbone. The commercial community has established the Asynchronous Transfer Mode (ATM) as the seamless interface between wide area networks and local area networks with graceful expansion of bandwidth capability. An ATM fiber optic backbone in the CVX will enable ship bandwidth growth to 2.4 gigabits per second and beyond.

The Panel finds that individual electronics suites with overlapping capabilities are utilized on today's carriers and other Navy surface combatants without a combat systems overview. The Cooperative Engagement Concept is a commendable step forward for the Navy to begin to address this problem. However, continued emphasis is required to ensure integration with the airborne links and legacy systems to which it is presently not connected. In addition, consistent systems oversight is strongly recommended, from R&D through acquisition, to eliminate technology gaps among subsystems. Properly directed and empowered, this oversight can also ensure the consolidation of individual subsystems such as common radar and receiver suites. Further, incoming radio frequency (RF) signals should be digitized as close to the receiving antenna as possible for all $C^4I$ systems in order to maximize signal-to-noise ratio, minimize interference, and maximize upgradability. The Panel strongly recommends that the DON maintain continuous vigilance on integration of $C^4I$ systems to ensure maximum CVX effectiveness.

The ability of the CVX to operate in all weather conditions is primarily an issue of ship size, in order to provide a sufficiently stable platform for aircraft operations. NAVSEA studies have shown that large carriers have a flight operations window that is approximately 50% larger than smaller carriers during certain rough weather seasons of the year in the North Atlantic, North Pacific, North Arabian Sea and South China Sea.

## CVX Flexibility - **Effectiveness**

CVX Flexibility requirements dictate the separation of carrier size from airwing size

In the present CVX COEA, large and small carriers supporting large or small airwings, respectively, are considered. A range of airwing sizes will be required to perform the full spectrum of anticipated CVX missions. The Panel concluded that CVX must be designed to support a large (80 aircraft) airwing and conduct flight operations in high sea states in order to execute the most demanding power projection missions. The challenge is to apply a system-oriented design approach supported with appropriate technology to ensure that CVX can normally be operated effectively with a smaller airwing, but can be surged to accommodate a larger airwing to address the most stressing missions on short notice. If successfully executed, this strategy will reduce operating costs during peacetime while retaining critical flexibility to enable the most demanding power projection requirements to be met.

## CVX Flexibility - **Availability**

- When and where needed
  - Speed
  - Reliability
  - Rapid reconfigurability
- As long as needed
  - Fuel & ordnance
  - Low maintenance
- Survivable against 21st century threats
  - Signature reduction
  - Protection (ship and personnel)
  - Recoverability

For maximum operational flexibility, CVX must be available; i.e., be able to perform when and where needed, for as long as needed, with systems fully operational, and without underway replenishment for the initial phase of conflict. The ship must also be able to survive against 21st century threats in order to be available after an attack.

Speed is a critical element for availability. Sustained sprints are only possible with a high power density, nuclear propulsion system. Such a system is more compact than conventional, fossil fuel plants with their fuel tankage, air intakes and exhaust uptakes. This allows greater self-sustainability with more space for the aviation fuel, spare parts, and ordnance for military missions, or other consumables for humanitarian missions.

Another element of availability is the speed with which the CVX can be reconfigured for a variety of missions. Rapid reconfiguration means more time at sea with systems fully operational. A common source of power provided by an all-electric ship and the incorporation of modular architecture for rapid reconfiguration will enhance operational flexibility.

Survivability requires attention to reduction of signatures, adoption of adequate protection measures, and the ability to recover from damage. Signature reduction efforts must include both electromagnetic and acoustic parameters. Mitigation of the CVX signature to a level sufficient to confuse identification rather than to hide it is believed by the Panel to be an achievable goal. Important aspects of ship protection are avoidance of magazine mass detonation and resistance to underwater shock. Innovative magazine protection approaches with reduced space and weight impact are sorely needed.

The vulnerability of critical, non-redundant systems such as a single island and a single aircraft recovery area must be addressed. Improved methods of personnel protection against harsh weather conditions and chemical, biological and radiological (CBR) threats are also necessary.

## CVX Availability-Survivability

Survivability through signature management:

- Low probability of intercept RF technology
- Multifunction wide bandwidth antennas
  - -- Invest in antenna consolidation technology
- Acoustic signature reduction
  - -- electric ship
  - -- improved propulsor

One of the more significant means for passive location of a ship is the detection of its RF emissions. To reduce that vulnerability, low probability of intercept (LPI) RF techniques such as spread-spectrum should be emphasized.

Detection of backscatter of active radar transmissions is another signature-related vulnerability which can be mitigated by consolidating antennas. The approximately 200 (largely metallic) antennas presently found on Nimitz class carriers span a size range from HF (10m to 100m) to millimeter wavelengths. Their combined effect results in a large electromagnetic signature. If the functions of these metal structures (as many as possible) are combined into wide-bandwidth, aperture antennas, each performing multiple functions, the signature can be reduced, and thereby the overall vulnerability of the ship. Antennas would be combined by functional groups (i.e., radar, EW and communications receivers; radar and EW transmitters; SATCOM UHF; UHF, HF, IFF and Line of Sight VHF). Antenna technology is presently evolving to support such combinations of functions. Given sufficient time and a modest, but consistent, R&D investment, reductions in numbers of apertures and their associated functions greater than 2 to 1 appear to be possible. It follows that the Navy's goal of consolidated multifunction wide-bandwidth apertures may be realizable. The present level of R&D funding is too small to develop the necessary antenna consolidation technology to the point required for CVX by 2013.

If consolidated on a single island, these multifunction apertures could be lost as a unit under severe combat conditions, disabling the entire $C^4I$ system. On the other hand, there are good arguments for co-locating them on a single structure, such as reduced signature and

efficient utilization of the space on the flight deck. Studies of the capability of an antenna island and its components to recover from various probable degrees of mechanical shock would also be required. Another important design issue concerns the ability of the ship to accommodate technology upgrades without disruption of operations.

The Panel views as urgent the need for consistent $C^4I$ systems engineering oversight, and the need for assured funding to take antenna consolidation technology and other critical $C^4I$ subsystems from the R&D stage through to acquisition without interruption. Only in this way can the CVX survivability and effectiveness goals be met by 2013.

Today's aircraft carrier, particularly at higher speeds, generates high levels of acoustic noise in the water, primarily due to propeller cavitation. This acoustic signature not only serves to unambiguously identify the carrier and aid in targeting it, but also severely compromises the ability to conduct anti-submarine warfare (ASW) operations in the area. Applying the lessons learned in propulsor design since the mid 1960s (when today's carrier propellers were designed) will substantially raise the speed at which cavitation becomes significant. The precise control of propeller torque and speed afforded by the employment of modern electric drive can not only aid in reducing CVX's acoustic signature, but may be useful for intentionally mimicking the acoustic signature of other ships.

## CVX Flexibility - **Reconfigurability**

Modular architecture and all-electric ship are key to affordable CVX reconfigurability

- Damage control
- New missions
- New technology

An essential element of CVX flexibility is the ability to reconfigure for damage control, adaptation for new missions and adoption of new technology. A key to lifetime CVX affordability is an all-electric ship with modular architecture.

The all-electric ship, with its common source of power for all systems, can be rapidly reconfigured in case of damage--power can be redirected to undamaged propulsion systems or mission critical combat systems. Electric catapult and arresting systems can be reconfigured.

A modular architecture with large accessible spaces and standardized utility interfaces will allow CVX to be rapidly reconfigured for different missions, including additional aircraft types or different suites of aircraft for joint service missions, or the accommodation of a large hospital facility for humanitarian activities. The absence of intake and exhaust ducts required in a fossil fueled ship eliminates a major obstacle in reconfigurability of ship spaces.

Over the 50-year service life of CVX, several generations of aircraft, $C^4I$ and HM&E technologies must be accommodated. The combination of a modular architecture, which allows rapid reconfiguration of mission critical payload and support spaces, and the all-electric ship, with its universal power source, is the only approach that can accommodate these anticipated changes in a cost effective manner.

## Reconfigurability - Damage Control

- Immediate electric power rerouting
  - Automatic
  - Prioritized
- Fast flight deck reconfiguration
- Propulsion system reconfiguration
  - Any prime power source with any propulsor

The all-electric carrier will be more resilient in responding to major casualties. With redundant main power buses, a zonal system for power distribution and an automated fault detection/casualty reconfiguration system, the provision of power to high priority users will be secure. Because other required power sources (steam, hydraulic, etc.) on the all-electric CVX may be provided locally, restoration of electric power should restore all services. The current CVN electrical and machinery systems reflect the control and manning doctrines of the 1960s. These systems depend heavily upon operator control inputs. Modern, fast electronic controls and sensors for electrical distribution equipment permit prioritization of load reduction and automated damage control reconfiguration with or without operator intervention. This type of control, in conjunction with the all-electric ship architecture, will maximize flexibility in allocating ship power resources.

Major damage to an element of the current CVN mechanical drive system can cause loss of a shaft which has major impacts on the speed and maneuverability of the ship. Electric-drive powered from a common propulsion bus with redundant sourcing and the use of modular propulsion motor architecture would permit distributing the effects of the loss to minimize speed and maneuverability impacts. An example of the manner in which universal use of electric-powered systems on CVX might enhance reconfigurability and reduce vulnerability to single-point failures is given in the next chart.

## Reconfigurability - New Missions

- Expanded joint missions
  - CTOL, STOVL, VTOL, rotary wing, UCAVs
  - Command modules
- New weapons
  - Transfer catapult electrical power to advanced weapons
- Humanitarian support
  - Berthing & messing
  - Hospital
  - Electric utility
  - Potable water

It is critical for CVX to be rapidly reconfigurable so that its performance on each assigned mission, including joint or cooperative missions, is optimized. The anticipated need for expanded Joint Services Missions, as well as the 50-year service life requirement, dictate that CVX must be able to reconfigure to accommodate multiple types and generations of aircraft, as well as $C^4I$ and combat systems. A carefully designed modular ship architecture and integrated electrical power source will provide the flexibility to make these changes in minimum time at minimum cost.

An all-electric CVX meets this flexibility requirement because electric power can be easily and quickly reallocated as changes such as more efficient ship propulsion, upgraded catapult power needs, and new weapon system requirements evolve. Additionally, when required for humanitarian missions, a nuclear-powered, all-electric CVX could supply electric power and potable water to a stricken area.

Modular architectural flexibility will enhance mission changes such as outfitting the carrier to operate as a hospital ship. It is essential that CVX be designed and built to speedily adapt to 21st century missions which cannot be well defined today. Service life allowances for space, weight, and support services growth can be reduced if provision for rapid reconfigurability is designed and built into CVX from the outset.

## Reconfigurability - New Technology

**Electric Ship Examples:**

- Internal propulsion motors
  - Drive flexibility
  - Low maintenance
- Podded propulsors
  - Performance upgrade
  - Eliminate rudders
  - Increased internal volume
  - Reduced construction cost and time
- Future advanced propulsors

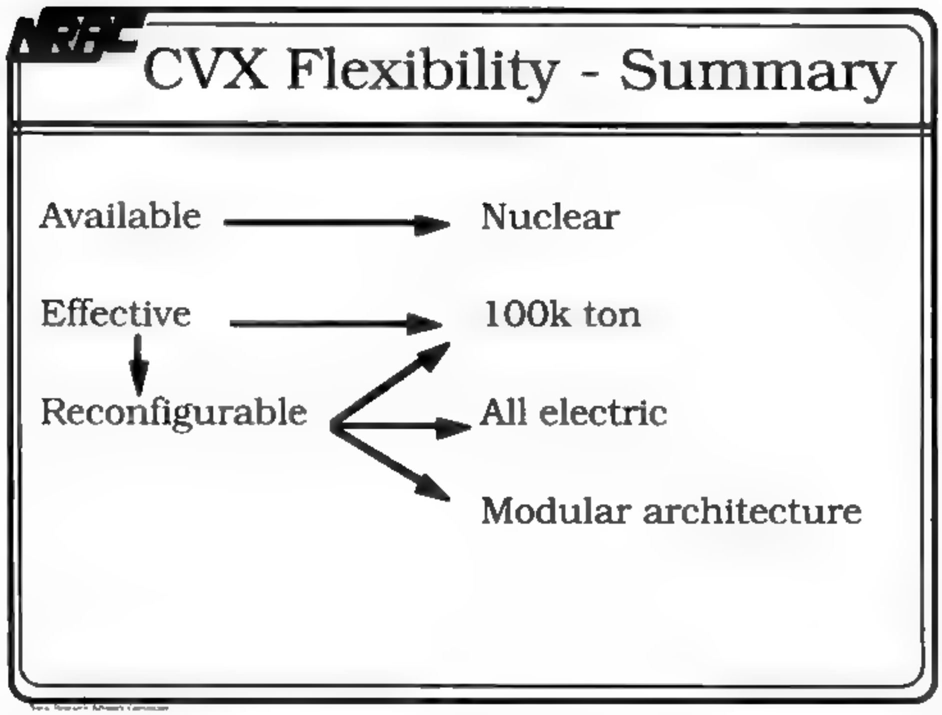
An all-electric CVX with modular architecture can also be readily reconfigured to accommodate new technologies. Commercial off-the-shelf (COTS) HM&E equipment mounted on pallets with standard interfaces for ship's services can be quickly replaced by exchanging pallets. Modular $C^4I$ workstations and equipment can be rapidly upgraded using concepts such as the "Smart-deck" approach. If anticipated during the design phase, an electric propulsion plant with internal motors can be updated to adopt steerable pods which in turn can be upgraded with advanced propulsors. Zonal electric distribution and ONR's Power Electronic Building Block (PEBBs) approach to power control make it possible to provide for upgrades of major elements with minimal disruption.

The ability to reconfigure an electric propulsion system incorporated in an all-electric ship has already been discussed. Cruise ships, which experience frequent speed variations, unlike cargo ships and tankers, have found conversion to electric drive reduces operating and maintenance manning requirements and costs. Although many of the advantages of electric drive can be achieved using electric motors mounted within the hull, electric motors mounted in external, steerable pods offer additional advantages. Remote location of the drive motors is made feasible by the superior reliability of electric machinery. Reliability can be further enhanced by the redundant, modular design of motors and power electronic controls.

Steerable podded propulsors offer significant improvement in acoustic signature due to reduced wake variation and improved propeller inflow characteristics. Such propulsors also provide improved ship maneuverability and increase available interior volume by elimination of shaft alleys, propulsion motors and rudder equipment

from the interior of the hull. Eliminating the tasks of surveying, boring, installing and aligning shafts and bearings in the hull should significantly reduce ship construction time and cost. Podded propulsors are gaining popularity in large commercial ships built in Europe. They are presently being installed in sizes up to 16 Mw. At least two credible electric machinery firms are offering sizes up to 24-30 Mw. If the improved performance, ease of upgradability and lower installation and operating costs of podded propulsion are to be available for CVX, the Navy will need to invest in the demonstration of a larger (48-60 Mw) unit. Although it may use the same technology as the smaller commercial units, there does not seem to be a commercial market to support the larger propulsor.

Should other propulsion technologies be developed that offer performance advantages for CVN (such as MHD or waterjet), conversion to such advanced technologies will be more easily and affordably accomplished starting from an electric-drive configuration than from a mechanical drive.




Four major features of CVX flexibility have been delineated:

- For maximum availability, the ship should have a **nuclear** power plant.
- For maximum effectiveness, in all weather and for all missions, the ship must be **big**, on the order of 100,000 tons.
- Finally, to be optimally reconfigurable, **modular architecture** and a common source of **electric** power are essential, in addition to large size.

## CVX Affordability - Ship Manning

- Continously insert widely used, demonstrated technology
  - e.g., automated warehousing
- Stand up Smart Carrier innovation team to evaluate suggestions and initiate bottom-up process review
- Design for reduced manning
  - Eliminate or minimize maintenance tasks
  - Mandate operator friendly systems with embedded training
  - Develop automated and/or remotely operated systems
  - Integrated $C^4I$

The success of the Smart Ship initiative on USS YORKTOWN demonstrates two key principles:

1. The commercial world has produced a great variety of widely used, thoroughly demonstrated, manning-reduction technology from which the DON can realize substantial benefit. The technology that proves to be of the most value will, of course, vary with ship class. A dramatic reduction of people on the bridge means a great deal for an Aegis cruiser, but has little impact on the total manning of an aircraft carrier. On the other hand, a computer program to optimize aircraft spotting on the flight deck, based on well established robot path-planning methodology, could have a substantial impact on aircraft carrier manning.

2. An innovation team, reporting to a responsible leader, can be an effective mechanism for producing, gathering, evaluating, and implementing ideas. For example, in response to the NRAC "Reduced Ship Manning Report" (November 1995), the Navy stood up the Smart Ship innovation team which quickly produced new mechanisms and approaches. Suggestions were solicited from the fleet, government laboratories, industry, and universities via the world wide web. Many of the suggestions received focused on widely used, thoroughly demonstrated, manning-reduction technologies.

Just creating a team does not guarantee success. Members of the Smart Ship innovation team credit the following:

- The team was established by the Chief of Naval Operations (CNO), and clearly had his attention and endorsement.

- The team members represented most of the constituencies involved, including requirements, platform, personnel, combat systems, HM&E, R&D, and ONR. The successful team members were highly competent and therefore difficult to extract from contributing organizations.

- The team members were given training in how groups can best be organized and conducted to think "out of the box."

- The CNO placed responsibility for success in the hands of vice admirals from the fleet, COMNAVSURFLANT (VADM Katz) and COMNAVSEA (VADM Sterner). They were instrumental in many ways; for example, they arranged for key people to be released from their home organizations for service with the team.

- The team was led by a captain with ship command experience, which provided both perspective and credibility.

- The team worked with a short, six-month deadline for producing a plan.

Thus, the success of the Smart Ship initiative was a matter of the right problem, the right people, the right training, the right time, the right advocacy, and a tangible deadline. It is important to recognize that the manpower reductions demonstrated on the USS YORKTOWN were not the result of an arbitrary manning reduction target. Instead, the team carefully measured the contributions of candidate technologies against the functions of the ship's crew, always with a view that work must come off the ship before people come off.

Some manning reduction ideas and technologies can be inserted into existing ships but, of course, many manning reduction ideas must be designed into a ship or ship systems to reap their benefit. In the area of eliminating maintenance requirements, for example, improved coatings and chamfered steel edges on structural members reduce the need for repainting. The use of corrosion resistant structural materials may altogether eliminate the need for painting in some areas. HM&E and combat systems with standardized, user-friendly interfaces employing embedded training serve to reduce the impact of personnel turnover as well as that of rapid reconfiguration of combat systems to support new missions. Reduction and automation of onboard ship administrative offices and functions is thought to hold the potential for substantial manning reduction. In the dimension of physical manipulation, particularly moving stores and waste, technology can be inserted from automated commercial warehousing practice. The manning required for damage control can be reduced by automated information-movement systems and team reorganization, as demonstrated by the USS YORKTOWN; and the wide use of inexpensive, wireless sensors can further reduce manning while increasing damage-control effectiveness through improved situational awareness. Reducing the manning required for aircraft movement, fueling, and arming is

more difficult, but a well focused S&T program should produce substantial gains.

For CVX it is critically important that manning reduction efforts address the complex interface between ship and airwing manning. Generally, as airwing manning is reduced, reductions in ship support personnel can also be achieved.

In summary, shipboard manning has historically been driven by a complex interplay between watchstanding, maintenance, training and damage control functions. If meaningful and lasting reductions in shipboard manning are to be achieved for CVX, it is essential that options for manning reductions in all four areas be explored with equal intensity and new balances between these critical roles be sought.

## CVX Affordability
## Operation & Maintenance

- Design to eliminate mid-life overhaul
  - Life-of-ship reactor core
  - Insert system upgrades and new systems continuously as required and available

- Rapid reconfiguration capability to adapt to missions and to reduce the length and frequency of overhauls
  - All-electric
  - Modular architecture

In order to best control O&M costs, the Panel recommends that CVX be designed with the goal of eliminating the mid-life overhaul. The constraint of a mid-life nuclear refueling could be overcome with life-of-the-ship nuclear reactor cores. The Panel acknowledges that designing a 50-year reactor core represents a significant extension of today's naval reactor core technology. The higher operating tempo that may result from reductions in Navy assets will directly affect the total energy these reactors will be required to produce. Nevertheless, life-of-the-ship nuclear cores are a desirable goal for CVX.

The principal benefit of eliminating the mid-life overhaul would be avoidance of the lengthy stand-down and disruption to other ship functions imposed by refueling the reactors. Such a commitment would also force upgrades and modernization to occur incrementally as required. If CVX is designed to be rapidly reconfigurable, it will be possible to make upgrades and install new systems more quickly and easily. This will completely divorce the decision to upgrade a particular system from the timetable of the mid-life overhaul. The rapid reconfiguration capability provided by an all-electric ship and modular architecture should reduce O&M costs by reducing the length and frequency of shipyard availabilities.

## CVX Affordability
## Operation & Maintenance (con't)

- Inject zero maintenance technologies
- Update supply systems
  - Total asset visibility -- the world is the warehouse
  - Automated warehousing technology

A method of reducing CVX O&M costs is to incorporate technologies that require no or little maintenance. This will allow for reductions in shipboard personnel. It will also reduce the amount of work to be done in the shipyard, which should reduce LCC.

Maintenance-free coating systems that will last for the life of the ship, or at least half that lifetime for the hull, tanks, voids, and topside surfaces should be developed and used. Another approach to low maintenance that is receiving wide attention is the use of condition-based maintenance for machinery as opposed to time-based maintenance. This ability to sense and evaluate material condition with distributed computing capability is available and should be applied to CVX systems.

An all-electric CVX, coupled with an accessible, modular, smart deck internal architecture, will provide the ability to readily change utilization of internal spaces. This means that during routine periods in port it will be possible to rapidly change and update the capabilities of the CVX to meet varying mission requirements or take advantage of new technological opportunities. Shipyard availabilities and shipyard overhaul time will also be reduced with associated maintenance cost reductions and increased ship utilization.

To be optimally effective, CVX shipboard supply systems must be integrated with the shore supply establishment. However, this must be interpreted in a broader sense than just a few limited DON supply focal points. CVX must be able to draw on all services' supply systems to meet the needs of the next century such as joint operations. To meet these needs, CVX operators must have real time visibility for location and status of relevant materials and this information should be meshed

with automated onboard warehousing capabilities. The result will be not only more efficient supply capabilities, but a reduction in one of the largest personnel commitments on the ship.

## CVX Affordability - Design/Build

- Select and adequately fund design/construction team early
- Identify and resolve design drivers early
- Perform cost/benefit analysis of CV design standards
- Maximize use of commercial standards and equipment
- Adopt state of the art:
  - Design methods and processes
  - Manufacturing and construction methods
- Capitalize on lessons learned
  - Three generations of submarine reactor design since Nimitz
  - IPPT approach used in aircraft production and NSSN

It is considered imperative that the CVX design/build team be selected and funded early, that it include participants who represent the users and maintainers as well as the designers and builders, and that the team be empowered to identify and resolve LCC related issues. To ensure that the most affordable design is selected for construction, both the designer and the builder must be involved because many design features can be implemented in different ways with varying impact on construction cost. To avoid using manpower intensive and costly manufacturing processes, feedback from the builder is necessary early in the design. Effective use of integrated product and process design teams (IPPT) has been successful in reducing construction and LCCs in both commercial and other military programs.

The effectiveness of this approach is strongly influenced by the abilities and commitment of the team leader and the degree to which participants are empowered to resolve issues. The savings achieved by the effective use of IPPTs can be further enhanced through the use of innovative contracting methods recently implemented on projects such as SC-21 and Arsenal Ship. Such procedures encourage a whole team approach to resolving critical design and construction issues. In order to minimize design cost and to ensure that attention is focused on those issues requiring more R&D, it is necessary to fix the design drivers (i.e., ship size, type of power plant, etc.) as soon as possible in the integrated design process. The flexibility designed into CVX by an integrated team of operators, maintainers, designers, builders and technology developers, should ensure faster and more affordable adaptation to changing military requirements in the future.

Navy design standards reflected in current CVNs must be thoroughly reviewed and subjected to rigorous cost/benefit analyses.

Significant cost savings will be achieved if non-essential or/and outdated standards are replaced with modern commercial equivalents. The tailoring of COTS equipment and technology to suit unique Navy ship requirements must be done by experienced designers with feedback from users.

A formal process should be established to ensure that CVX designers remain knowledgeable of the most up-to-date design methods developed and used in other fields. The use of techniques developed by the Boeing Corporation for commercial aircraft and by the design team for the new attack submarine (NSSN) should be considered as starting points. The design-build methodology which incorporates concurrent engineering and advanced design tools has revolutionized ship design and construction. These processes, which focus on getting the right people in the right place at the right time, significantly enhance the affordability and flexibility of the design and construction process. The concurrent involvement of the design, construction, and O&M organizations early in the design process will enable incorporation of new technology and development of innovative designs in the most efficient manner. Additionally, completion of the design efforts prior to the start of construction allows the shipbuilder the most flexibility in sequencing the construction phase.

The commercial shipbuilding industry, in order to be competitive in the world market, has adopted many manufacturing and construction methods that reduce the cost of building ships. Similar gains have been made in the automotive and aircraft industries. Many of these practices may be applicable to naval construction; however, current design standards for Navy ships may preclude their use. It is essential that, in the design process, these modern commercial methods be given full and careful consideration. This requires that the design/build team be knowledgeable of the evolving state-of-the-art and how it applies to naval construction.

The Naval Reactors (NAVSEA 08) organization should ensure that the design practices and technology used in developing the NSSN are applied to design of a new aircraft carrier nuclear propulsion plant, without sacrificing those unique features required of a carrier reactor plant. To fully implement the concept of the flexible electric ship, increased liaison with the ship designers and operators will be necessary. To insure that the objectives of cost and manning reductions are met, propulsion plant designers should seek to understand and apply commercial standards and practices in ways that complement the safety and military ruggedness of current naval nuclear plants.

## CVX Conclusions

- An all-electric, modular, nuclear, 100k ton carrier is flexible because it is
  - Reconfigurable
  - Available
  - Effective
- The keys to affordability are
  - All-electric and modular design
  - New methods and technologies
  - Reduced manning

The initiation of a new carrier design effort evokes many technical debates, excites many constituencies, and invites many proposals for S&T spending. Perhaps most energetically debated are the issues of conventional versus nuclear power, and ship size. The NRAC CVX Flexibility Panel found arguments favoring large, nuclear-powered carriers to be persuasive when considered in the light of reduced overseas bases and the wide spectrum of rapidly evolving crises which are likely in the 21st century environment.

In the heat of debates over size and energy source, it is easy to lose sight of other important issues, leading to the neglect of important S&T goals. The first of these issues centers on the all-electric ship. By insisting on an all-electric ship, the Navy will ensure O&M cost savings, reconfiguration flexibility and arguably, design and construction savings as well. This is true for nuclear-powered ships and perhaps even more critical for conventionally powered ships. To achieve the benefits of the all-electric ship, the Navy must support S&T work on:

- Electric drive (preferably podded)
- Integrated electric power
- Power electronics building blocks
- Electric catapult and arresting gear
- Electric elevators and other auxiliary systems

The ability to rapidly and affordably reconfigure for damage control, changing missions and changing technologies must be designed

into CVX from the beginning. The all-electric ship concept supports this approach. Large areas, high in the ship, must be provided with easy access and standard interfaces to allow for the rapid exchange of pre-equipped, mission specific modules. Elsewhere in the ship, $C^4I$ systems, combat systems and HM&E equipment installations should be modularized or palletized to allow rapid exchange. To ensure that this can be accomplished without compromising availability or survivability, S&T investment in acoustic and shock isolation of palletized and/or modularized systems containing COTS hardware is required. Especially careful attention should be paid to modularity in the interface between the airwing and the carrier. Reconfiguring a carrier for a different airwing should be a matter of quickly exchanging carefully configured work and storage modules.

Methods and technologies oriented toward ensuring affordability are grouped here into the following categories:

- Manning reduction
- Nuclear plant
- SCN
- Other S&T innovation.

Manning reduction translates not just into lower personnel cost, but also into increased space for improved habitability, mission flexibility and endurance. Accordingly, there is a need for S&T investment in the following areas:

- Low cost, wireless sensors (support current ATD and look beyond)
- Automated stores handling, building on commercial technology
- No and low maintenance technologies for surface coatings and HM&E systems
- Automated waste handling and environmentally acceptable disposal
- Automated aircraft spotting
- Automated aircraft movement, fueling, and arming (difficult, but high impact).

Some of these initiatives may be a matter of inserting well-established commercial technology. Others require more substantial S&T investment. In all systems, the DON should stress operator-friendly

human-computer interfaces, generally reflecting commercial standards, and embedded training in all computer-based systems.

While the Panel feels that it would be inappropriate for nuclear plant S&T to dominate the S&T budget, there are nuclear plant related S&T opportunities that merit attention, including:

- Cost reduction
- Manning reduction
- Elimination of mid-life refueling

## CVX Recommendations

- Insist on:
  - All-electric design
  - Modular architecture
  - Development of integrated aperture antennas
  - Affordability promoting methods and technologies
- Select nuclear, 100k ton design

In the SCN area, the Panel's principal recommendations are that the DON should select and fund the CVX designer and builder early and should fix CVX design drivers as quickly as possible. The Panel also recommends that the Navy should make the S&T investment necessary to:

- Adopt effective, state-of-the-art design methods and processes (simulation based design, IPPTs)
- Adopt state-of-the-art manufacturing and construction methods (modular pre-outfitted elements, automated welding)
- Apply lessons of three generations of submarine reactor R&D and design since Nimitz

The Panel notes that the DON's Smart Ship innovation team provides one model of how manning improvements can be achieved. The same concept, detailed previously, could be generalized to CVX affordability.

<u>Other S&T Needs:</u>

The $C^4I$ area lacks the coordination needed to ensure seamless integration and maximum effectiveness. Opportunities include reduction of component and software redundancy, as well as reduction of manning and training costs. Accordingly, a $C^4I$ architect is needed, along with consistent funding to meet the following objectives:

- Improved total awareness via an integrated information system based on:
    - ⇨ High bandwidth fiber optic backbone
    - ⇨ Digitized receiving antenna outputs
    - ⇨ Data rates in excess of current MILSAT capability
- Integrated phased array antennas to provide:
    - ⇨ Greater than 2:1 aperture and function consolidation
    - ⇨ Reduced radar cross-section
- Low probability of intercept RF technology

Attention to survivability is critical if CVX is to be effective in the 21st century threat environment. Needs in this area include:

- Reduced/disguised acoustic signature via electric drive
- Reduced acoustic signature via improved propeller design (S&T has been done; need to use state-of-the-art design and manufacturing)
- Reduced radar cross-section and IR signatures
- Improved protection against shock from underwater explosions
- Innovative magazine protection approaches to reduce space, weight and cost impacts
- Reduced vulnerability of critical, non-redundant elements such as a single island or single aircraft recovery facility
- Protection of personnel against harsh weather and CBR threats

At this juncture, 15 years before IOC, it is certain that we cannot predict the directions the commercial sector will take with regard to computer software. Many heuristics that applied formerly may well be counter-productive in the future. For example, it was true in the past that the DON should avoid the use of proprietary software, at the risk of extortionary pricing for that software. Today, however, to insist on a completely vendor neutral software solution often leads to a system that is either built to order, or inadequate. Either solution is expensive; however, proprietary systems with huge commercial user bases can be obtained at competitive rates.

In summary, a large, nuclear-powered CVX will provide the potential for maximum flexibility in terms of effectiveness and availability. In order to take best advantage of this potential, CVX should be an all-electric ship with modular architecture to allow rapid and affordable reconfigurability for enhanced damage control, adaptation to new missions and adoption of new technologies. Survivability against probable 21st century threats must be a priority for CVX designers and this requires reduction of acoustic and electromagnetic signatures to decrease the likelihood of being targeted. Affordability should be pursued through adoption of proven commercial methods and technologies for reducing manning, and O&M and construction costs.

## Appendix A. List of Acronyms

| | |
|---|---|
| ASN(RD&A) | Assistant Secretary of the Navy (Research, Development and Acquisition) |
| ASW | Anti-Submarine Warfare |
| ATD | Advanced Technology Demonstration |
| ATM | Asynchronous Transfer Mode |
| $C^4I$ | Command, Control, Communications, Computers and Intelligence |
| CBR | Chemical/Biological/Radiological |
| CNO | Chief of Naval Operations |
| COEA/AOA | Cost and Operational Effectivness Analysis/Analysis of Alternatives |
| COMNAVSEA | Commander, Naval Sea Systems Command |
| COMNAVSURFLANT | Commander, Naval Surface Forces Atlantic |
| CONUS | Continental United States |
| COTS | Commercial Off-the-Shelf |
| CTOL | Convential Take Off/Landing |
| CV | Carrier |
| CV/ARG | Carrier/Amphibious Ready Group |
| CVBG | Carrier Battle Group |
| CVN | Nuclear Powered Carrier |
| CVX | Future Carrier |
| DARPA | Defense Advanced Research Projects Agency |
| DoD | Department of Defense |
| DON | Department of the Navy |
| EW | Electronic Warfare |
| FAA | Federal Aviation Administration |

| | |
|---|---|
| FSAD | Full Scale Advanced Demonstration |
| HF | High Frequency |
| HM&E | Hull, Mechanical and Electrical |
| IFF | Identification Friend or Foe |
| IOC | Initial Operating Capability |
| IPPT | Integrated Product and Process Design Team |
| JSF | Joint Strike fighter |
| LCC | Life Cycle Cost |
| LPI | Low Probability of Intercept |
| MHD | Magnetohydrodynamics |
| MILSAT | Military Satellite |
| Mw | Megawatts |
| NATOPS | Naval Aviation Training and Operational Procedures Standardization |
| NAVAIR | Naval Air Systems Command |
| NAVSEA | Naval Sea Systems Command |
| NRAC | Naval Research Advisory Committee |
| NRaD | (SPAWARSYSCEN as of 30 Sep 97) Space and Naval Warfare Systems Center |
| NRL | Naval Research Laboratory |
| NSSN | New Attack Submarine |
| NSWC-CD | Naval Surface Warfare Center, Carderock Division |
| NSWC-SSES | Naval Surface Warfare Center - Ship System Engineering Station |
| O&M | Operation and Maintenance |
| ONR | Office of Naval Research |
| ONR IFO | Office of Naval Research Internationl Field Office |

| | |
|---|---|
| OPNAV | Office of the Chief of Naval Operations |
| OSD (A&T) | Office of the Secretary of Defense (Acquisition and Technology) |
| PEBBs | Power Electronic Building Block |
| PEO - CLA | Program Execution Officer - Carriers/Littoral/Amphibous |
| R&D | Research and Development |
| RDT&E | Research, Development, Test and Evaluation |
| RADM | Rear Admiral |
| RF | Radio Frequency |
| S&T | Science and Technology |
| SATCOM | Satellite Communications |
| SCN | Ship Construction Navy |
| SPEC OPS | Special Operations |
| STOVL | Short Take-off/Vertical Landing |
| SWATH | Small Wetted Area Twin Hull |
| UAV | Unmanned Aerial Vehicle |
| UCAV | Unmanned Combat Aerial Vehicle |
| UHF | Ultra High Frequency |
| UK | United Kingdom |
| USAF | U.S. Air Force |
| USMC | U.S. Marine Corps |
| USN | U.S. Navy |
| VADM | Vice Admiral |
| VHF | Very High Frequency |
| VSTOL | (Very Short) Take-off/Landing |
| VTOL | Vertical Take-off/Landing |

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